

Index

Asorption coefficient 75
AES *See* Auger electron spectroscopy.
AFM 15, 22
 alteration of structure *See* laser-induced damage and ion beam bombardment.
 angle-resolved scattering (ARS) 17–19, 22, 23
 ARS 17–19, 22, 23
 atomic force microscopy (AFM) 15, 22
Auger electron spectroscopy (AES)
 composition of optical coatings 89
 multilayer depth profile 107
 summary 181
 thin film analysis 96–98

Back reflection distribution function (BRDF) 102
 bandgap in alloying 56–57
 bonding 42, 45, 60–63, 91–95, 108, 148
 BRDF 102

Carbon phases in CVD diamond 72
 cathodoluminescence 76–78, 182
 chalcogenide glasses 60–63
 charge state 170–171
 coatings *See* films and optical coatings.
 complete pseudodielectric function 43–44
 complex dielectric function 32
 composite dielectric function 34
 confocal microscopy 20
 continuous-wave (CW) laser 157–163
 cross-section transmission electron microscopy (XTEM) 29, 39, 102–104
CVD diamond
 absorption coefficient 75

crystal growth 73
 defects 74, 76–79
 deposition 71, 72–74
 film growth 73–74
 impurities 75
 lattice 74–75, 76, 78
 layer production 74
 optical properties 74–76
 polishing 79–80
 twins 78–79
X-ray window, use as 80–81
CW laser 157–163

Damage to material *See* laser-induced damage and ion beam bombardment.
 diagnostics, *in situ*
 Gaussian laser 165
 metal surfaces 166–168
 particle emission 168–170
 photothermal displacement 165–166, 168
 target excitation 165
diamond *See* CVD diamond.
 dielectric surface damage 170
 doped glass 165
 doping for stress control 127–128

EDS 102, 184
EELS *See* electron energy-loss spectroscopy.
 electron energy-loss spectroscopy (EELS)
 laser-induced damage detection 174
 multilayer phase composition 112
 summary 183
 thin film analysis 102

- electron microprobe analysis (EMA) 102
electron nuclear double resonance (ENDOR) 150
electron paramagnetic resonance (EPR) 150, 162
ellipsometers 29–32
ellipsometry *See also* spectroscopic ellipsometry.
 basic discussion 29–30
 composite dielectric function 34
 data analysis 32–34
 nulling ellipsometry 30, 33
 pseudodielectric function 33
 time-resolved 32
EMA 102
ENDOR 150
energy-dispersive spectroscopy (EDS) 102, 184
epitaxial films 51–56
EPR 150, 162
evaporated films 62
EXAFS 102
extended X-ray absorption fine structure (EXAFS) 102
extinction coefficient 36, 108
- F-center holes 150
film growth
 analysis 45
 control of 42
 diamond 73–74, 79
 epitaxial 51–56
 molecular beam epitaxy 39, 42, 54
 monitoring in real time 41–44
 studies of 44–45
films *See also* thin films.
 delamination 118
 deposition 10
 diamond films 79–80
 epitaxial 51–56, 57
 failure 120
 impurities 94
 layering 38–40
 polishing diamond films 79–80
 pseudodielectric 42–44
 refractive index 28, 32
 stress 117–130, 173
 thickness measurement 28, 37, 39
Fourier transform infrared spectroscopy (FTIR) 185
- Fresnel coefficient 28, 33, 158
Fresnel reflection ratio 32
FTIR 185
- Gaussian laser 159, 165
- glass
 chalcogenide 60–63
 extinction coefficient 36
 ion beam bombardment 145–146
 optical function 35–37
 refractive index 35–37
 semiconducting 60–63
- Halides 148–149
high-resolution electron microscopy (HREM) 78
HREM 78
- Impurities
 control of film stress 127–128
 diamond 75
 optical films 91, 94, 97
infrared ellipsometry 44–45
infrared spectrophotometric analysis 107–108
interferometer 130
ion beam bombardment
 collisions 143–144
 defect centers in halides 148–149
 embedment depth 141
 implantation damage 142
 ion–solid interactions 142–143
 LiNbO₃ 152–153
 microstructural changes 144–145
 nuclear stopping 142–143
 point defect types 145
 preparation of optical components 153–154
 stress caused by 151–152
- Laser-induced damage
 accumulation 163–165
 conditioning of optic surface 161–163
 damage as transitional phase 158–160
 damage identification 160–161
 definition 158–160
 fluence 159–160

Fresnel coefficient 158
Shock wave 158–159
statistical data 159–160
threshold 159–162
threshold reduction 163–164
laser ionization mass analysis (LIMA) 169
lattice
atom displacement 142
constant 53, 54, 56, 57
diamond 74–76, 78
distortion 119
dynamics 51
expansion 152
mismatch 57
strain 58–59
layering in optical coatings 87–88
layers *See* films.
LEED 174
light microscopy 186
light scattering in surface analysis 17–20
LIMA 169
low-energy electron diffraction (LEED) 174

Mapping, surface 15, 20, 22
mechanical profilometer 16–17, 20–21
microstructure
changes from ion bombardment 144–145
growth 42
multilayer 109–111
optical coating 89, 102, 104
thin film 89, 102
microwave plasma CVD 72
microwave plasma torch 72, 78
modular spectroscopy 187
molecular-beam epitaxy 39, 42, 54
molecular structure 95
multilayer optical coatings, 106–112
multiple-wavelength real-time ellipsometry 42–44

Nomarski microscope 12, 15–16, 20, 22, 23
nondestructive measurements 166
NRA *See* nuclear reaction analysis.
nuclear reaction analysis (NRA)
multilayer composition 109
multilayer depth profile 107
summary 188

thin film analysis 96, 101–102
nulling ellipsometry 28, 30, 33

Optical coatings
amorphous 88
bonds 91–94
chemical composition 92–94, 96–102, 107–109
depth profiling 108–109
impurities 91, 94, 97, 108
microstructure 88, 102–106, 109–111
molecular structure 95
multilayer 87–88
phase composition 96, 108
single layer 89–91
optical constants 88, 90–91
optical function 33–37, 39, 41
optical microscope 28
optical profilometer 16–17, 20–21
optical reflection measurements 28, 29
optical scatterometry 189
optical spectroscopy 88, 92–95
opto-electronic thin films 56–59

P_{DT} 165–168, 191
PEM 30–32, 34–36
phase composition 96, 108, 112
phases, thin film 171, 172
phonon generation in diamond 74–75
photoelastic modulator (PEM) 30–31
photoluminescence 190
photothermal displacement technique (PDT) 165–168, 191
PME 30–32, 34–36
polarization modulation ellipsometer (PME) 30–32, 34–36
polishing 10–11, 162, 163
postmortem damage diagnostics 170–174
profiling, instruments for 18
profilometer 16–17, 20–23
pseudodielectric function 28, 33, 42

Quartz 147–148

Radio frequency plasma torch 72
RAE 30–32

- Raman scattering 50–55, 59–60, 66
Raman spectroscopy
 diamond 72, 73
 epitaxial films 51, 52, 54
 evaporated films 62
 laser-induced damage 172–173
 molecular structure of optical films 95–96
 multilayer phase composition 108, 112
 multilayer stability 111
 phases in thin films 172
 strain 57
 stress 134–136
 summary 193
- RBS *See* Rutherford backscattering spectrometry.
reflection measurements 28, 29
refractive index 35–37
rotating analyzer ellipsometer (RAE) 30–32
rotating polarizer ellipsometer (RPE) 30–31
RPE 30–31
Rutherford backscattering spectrometry (RBS)
 film structures 38–40
 multilayer composition 109
 multilayer depth profile 107
 random atoms in quartz 147, 148
 summary 194
 surface characteristics 29
 thin film analysis 96, 100–101
- S**sapphire 149–151
scanning electron microscope (SEM)
 coating microstructure 89, 102, 104
 diamond defects 77
 diamond film morphology 72–73
 multilayer microstructure 110–111
 summary 195
 surface roughness 15
scanning transmission electron microscope (STEM)
 coating microstructure 89, 102, 105
 multilayer microstructure 110
 multilayer stability 111–112
 summary 196
 thin film surfaces 15
scanning tunneling microscopy (STM) 15, 22, 29, 197
scatterometry 189
scratches, surface 12
SE *See* spectroscopic ellipsometry.
- secondary ion mass spectroscopy (SIMS)
 composition of coatings 89
 multilayer depth profile 107
 summary 198
 thin film analysis 96, 99–100
- SEM *See* scanning electron microscope, semiconductor
glass 60–63
microcrystalline 63–66
Raman scattering in 59–60, 66
thin film alloys 51–55
semi-infinite substrate 32
Shockwave 158–159
SIMS *See* secondary ion mass spectroscopy.
single-wavelength real-time ellipsometry 41–42
spectroscopic ellipsometry (SE) *See also* ellipsometry.
 data analysis 32–34
 film thickness 39
 microstructural determination 34–35
 multilayer analysis 39
 near-surface analysis 32–34
 optical function of glasses 35–37
 optical function of layers 39
 refractive index 35–37
 temperature considerations 34–35
- STEM *See* scanning transmission electron microscope.
STM 15, 22, 29, 197
strain in thin films 57–59
stress in optical films
 compressive 120, 123
 control of 124–130
 deposition-process dependent 118
 explanation models 122–123
 failure caused by 120
 intrinsic 118–123
 lattice deformation 119–120
 measurement techniques 130–136
 tensile 117–118, 120–123
 thermal 120–122
substrate
 deformation 119, 120
 dielectric function 32
 pseudodielectric function 42
 refractive index 33, 37
 semi-infinite 32
 silicon, amorphous crystals on 41–42
 stress-induced deformation 130–132

superlattice in thin films 58, 59
surface mapping 15, 20, 22
surface modification of optical materials 141–154
surface roughness
 deposited films 10
 effect on optical measurements 14
 magnetic disc 22
 measurements of 14–20
 physical attributes 10–11, 13–14
 polishing, effects of 11–12
 profiling tools 18
 types 10–12

Target excitation 165
TEM *See* transmission electron microscopy.
thickness measurement 28, 37, 39
thin films
 composition 88–96
 conditioning 162–163
 damage 166, 168
 diamond 64, 71, 73–74
 epitaxial 51–52
 laser damage diagnosis 170
 layering in optical coatings 87–89
 magnetic 10
 microstructure 89, 102–106
 optical coatings 87–89, 91–106
 opto-electronic 56–59
 polishing 162, 163
 preparation 64
 semiconductor glasses 60–63
 semiconductor, microcrystalline 63–66
 strain 57–59
 stress 119–123
 surface analysis 96–102
 thickness determination 39
time-resolved ellipsometry 32, 40–41
TIRM 22, 200
TIS *See* total integrated scattering.

topographic maps 22
total integrated scattering (TIS)
 optical thin film microstructure 102
 surface properties 17–19, 22
 surface statistics 23
total internal reflection microscopy (TIRM) 22, 200
transmission electron microscopy (TEM)
 diamond defects 72
 epitaxial layers 51, 52
 lattice structure 55
 multilayer instability 111–112
 multilayer microstructure 110
 optic coating microstructure 89,
 102–104
 summary 202
twins 78–79

Ultra-high vacuum studies 169

Variable-angle spectroscopic ellipsometry (VASE) 39, 203
VASE 39, 203

XPS 96, 100, 206
X-ray diffraction (XRD)
 coating microstructure 89
 crystallographic phase identification 55
 film stress 133–134
 multilayer instability 111
 multilayer phase composition 112
 summary 204
X-ray fluorescence (XRF) 102, 205
X-ray photoelectron spectroscopy (XPS) 96,
 100, 206
X-ray window 80–81
XRD *See* X-ray diffraction.
XRF 102, 205
XTEM 29, 39, 102–104